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QUARTERMASTER RESEARCH AND ENGINEERING CENTER
NATICK, MASSACHUSETTS

CHEMICALS AND PLASTICS DIVISION
Plastics Section Report No. 1

THE FEASIBILITY OF USING FIBER GLASS REINFORCED
PLASTICS TO FABRICATE PETROLEUM FUEL TANKS

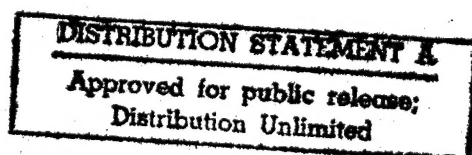
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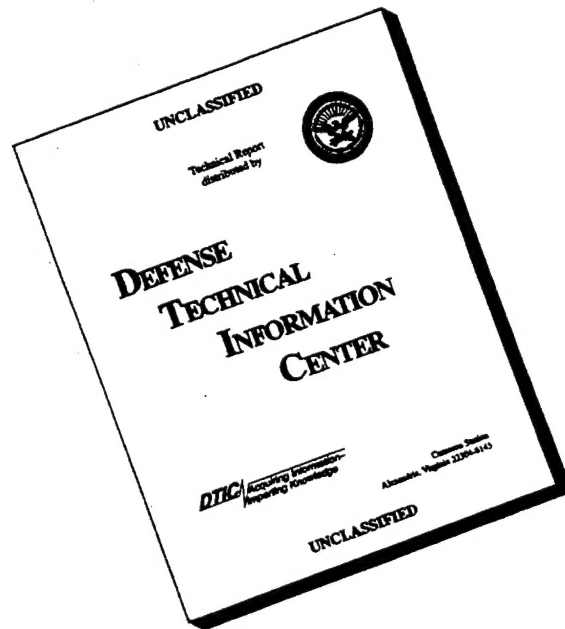
January 1958



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CODE SHEET

<u>Sample Number</u>	<u>Company</u>	<u>Company Sample Number</u>
1	Beetle Boat Co., Inc.	
2	Carl N. Beetle Plastic Corp.	
3	Bellingham Shipyards Co.	
4	Bellingham Shipyards Co.	
5	Durez Plastics Div., Hooker Electrochemical Co.	
6	Durez Plastics Div., Hooker Electrochemical Co.	
7	Durez Plastics Div., Hooker Electrochemical Co.	
8	Fibercast Corp.	E-200
9	Fibercast Corp.	G-300
10	Fibercast Corp.	H-350
11	Fibercast Corp.	J-500
12	Haveg Industries, Inc.	Pla-tank D
13	Haveg Industries, Inc.	Pla-tank H
14	Haveg Industries, Inc.	Pla-tank S
15	Haveg Industries, Inc.	7710
16	Haveg Industries, Inc.	7730
17	Mechtronics Co., 423 W. Coulter St., Philadelphia 44, Pa.	
18	Victory Plastics Co., Hudson, Mass.	

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FOREWORD

At the request of the Mechanical Engineering Division, the Chemicals and Plastics Division investigated the feasibility of using fiber glass reinforced plastics for the fabrication of rigid petroleum fuel tanks.

CONTENTS

	<u>Page</u>
Summary	iv
Introduction	1
Analysis of Problem	1
Laboratory Work	1
Discussion of Laboratory Work	2
Industrial Contacts	2
List of Possible Contractors	4
Conclusions and Recommendations	7
Bibliography	8
Appendix	9

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SUMMARY

Reinforced plastics have been evaluated as replacements for metal for fabricating 600-gallon petroleum fuel tanks which can be transported by truck. On the basis of the work done, it appears feasible to use reinforced plastic materials for 600-gallon POL tanks; however, it is recommended that reinforced plastics should be further investigated both in our own laboratories and by means of a development contract.

Factors which were considered are listed, analyzed, and discussed. These include:

Materials: Resins catalysts and other additives; reinforcing fibers.

Design of tanks: For chemical resistance; for mechanical strength of tank and mountings.

Method of construction of tanks: Laboratory solvent resistance tests similar to tests used on rubbers were run on 18 samples of reinforced plastics recommended and supplied by plastics manufacturers. Solvent resistance of fiber glass reinforced polyester and epoxy resins (not more than 6 per cent change in volume) is very much better than that of "oil resistant" synthetic rubbers and appears to be satisfactory, based on short term laboratory tests. Details of the test methods used and results are given in the Appendix.

Contacts were made with material suppliers and with reinforced plastics fabricators. A list is given of 6 fabricators believed to be especially qualified for a development contract, and also of 9 others experienced in general reinforced plastics fabrication.

Four guide lines are recommended for the design and construction of prototype tanks:

1. The principal reinforcement shall be fiber glass cloth.
2. Resin diluents shall be kept at a minimum.
3. Resin inhibitors and accelerators shall be kept at a minimum.
4. Chemical bonding shall be used for assembly of tank components.

It is recommended that further solvent resistance tests be run, using larger samples of plastics and actual fuels instead of the test solvents used in tests.

In addition, it is recommended that work on design and construction of tanks be carried out under a development contract to include complete mechanical design of the tank and construction of prototype tanks to meet the military characteristics and other requirements.

THE FEASIBILITY OF USING FIBER GLASS REINFORCED PLASTICS TO FABRICATE PETROLEUM FUEL TANKS

INTRODUCTION

An investigation was conducted to determine the feasibility of using fiber glass reinforced plastics for the fabrication of 600-gallon fuel tanks. Such tanks would be transportable by truck and used to carry aviation fuels, motor fuels, or JP-4 jet fuels. Metal tanks of 600-gallon capacity have been built.

The investigation included (a) laboratory determinations of the solvent resistance of recommended reinforced plastic materials and (b) a survey of material suppliers, reinforced plastic fabricators, and other government laboratories to review prior work in this and related fields and design problems which would be encountered.

ANALYSIS OF PROBLEM

The development of satisfactory plastic 600-gallon POL (petroleum, oil, lubricant) tanks resistant to petroleum-base fuels depends upon several factors. These include:

1. Use of one or more chemical and weather-resistant resins which will not affect the fuels adversely or be deteriorated by the fuels or by outdoor weathering.
2. Use of fiber glass and/or other fibers and fillers in the proper forms.
3. Competent plastic engineering design of the complete tank to meet service conditions and military characteristics.
4. Construction of the tanks by experienced fabricators using proper resins and reinforcing agents according to an approved engineering design.

LABORATORY WORK

Laboratory screening tests were run in this Division using the organic solvent resistance test. Eighteen fiber glass reinforced plastic samples selected and submitted by suppliers for possible use in making 600-gallon tanks were found satisfactory. The details of the test methods are given in the Appendix.

No laboratory work can be done in this Division on items mentioned in Analysis of Problem. These are engineering questions and can be completely answered only in cooperation with industry; for example, through a development contract.

The results of the solvent resistance tests are given in Table I which follows.

DISCUSSION OF LABORATORY WORK

The plastic materials tested, as compared to synthetic rubber compounds, were only very slightly affected by the liquids used.

In contrast to synthetic rubbers, all of which swell to some extent, about 40 per cent of the plastic samples showed slight shrinkage. The maximum swelling (+5.4 per cent) and the maximum shrinkage (-3.7 per cent) both occurred with Type I liquid (Table I). Some synthetic rubbers will swell 150 per cent or more with Type II liquid and only very few "oil resistant" rubbers will swell as little as 5 per cent with either Type II or Type III liquid (Table I) under comparable conditions of exposure. It should be reiterated, in considering the results of these tests, that the samples tested were all selected by the suppliers because of their known resistance to chemicals.

The results of these tests indicate that plastic materials resistant to POL fuels can be selected and performance characteristics defined. Polyester resins reinforced with fiber glass are reported to have been used successfully for similar applications. Other types of resins, particularly epoxy resins, also appear to be acceptable. Therefore, on the basis of present knowledge, properly specified reinforced plastics made of either polyester or epoxy resins and fiber glass are recommended for further evaluation for POL-resistant tanks. Further information is needed, such as results of chemical exposure tests to be run at different temperatures and times, using actual fuels and larger samples of plastic. The fuels should be analyzed for possible contamination, such as an increase in gum content. The plastic samples should also be subjected to vibration during exposure. It would be feasible to conduct this testing work concurrently with design work on the 600-gallon tanks.

INDUSTRIAL CONTACTS

Contacts have been made with a number of companies which are commercial producers of reinforced plastic structures. Fifteen of them are listed. The first 6 of these companies have produced plastic tanks, tank trucks and/or other containers for handling liquids, including petroleum products. None of these tanks were of the right capacity or design for the proposed application. The experience of these companies indicates, however, that it is feasible to design and build 600-gallon POL fuel tanks which are physically suitable for use on trucks.

Engineering design of the tanks required can be carried out concurrently with development of the exact specification for the resins, and it is recommended that the engineering work be done under an outside

TABLE I

VOLUME INCREASE OF REINFORCED PLASTICS AFTER 5-DAY IMMERSION IN SOLVENTS AT ROOM TEMPERATURE
(Approximately 70° to 85°F.)

Sample Number	Thickness (inches)	Form	Resin	Reinforcement*	Resin Weight (% of Total)	Volume Increase (%)		
						Type I	Type II	Type III
1	5/16	Panel	Polyester	Fiber glass mat		+3.4	+1.7	-0.35
2	1/4	Panel	Polyester	Fiber glass mat		+3.9	+1.45	-2.68
3	3/8	Panel	Polyester Hetron	Fiber glass		+0.52	-0.40	-0.22
4	3/8	Panel	Polyester Vibrin	Fiber glass		+0.05	-0.37	-0.37
5	1/4	Panel	Polyester Hetron 32A	Fiber glass, 15 plies No. 1000 cloth	54.2	-0.33	+0.6	+0.43
6	1/4	Panel	Polyester Hetron 72	Same	52.7	+0.22	-0.27	+0.11
7	1/4	Panel	Polyester Hetron 92	Same	56.0	-3.7	-3.1	-2.7
8	3/16	Pipe	Epoxy	Fiber glass, braided multi-layer		+5.4	+2.0	+1.1
9	3/16	Pipe	Epoxy	Same		+3.95	+1.5	+2.05
10	5/32	Pipe	Epoxy	Same		+5.2	+4.4	+0.6
11	1/4	Pipe	Epoxy	Same		+3.5	+3.35	-0.53
12	3/16	Panel	Polyester	Fiber glass		-0.41	+2.2	+0.36
13	3/16	Panel	Polyester (Fire-resistant)	Fiber glass		-0.82	+1.0	-0.41
14	1/8	Panel	Polyester	Fiber glass		-0.44	+1.6	+0.35
15	3/16	Panel	Polyester	Fiber glass		-0.70	+0.31	+0.39
16	3/16	Panel	Polyester	Fiber glass		-2.4	-2.0	-2.1
17	5/16	Panel	Polyester	Fiber glass cloth		+3.05	+1.15	+2.9
18	3/32	Panel	Polyester Hetron 32A	Fiber glass 183 cloth & 2 oz. mat	60	-0.79	+0.3	+0.15
Maximum swelling (+values)						+5.4	+4.4	+2.9
Maximum shrinkage (-values)						-3.7	-2.0	-2.7

*Based on information received from the suppliers of the samples as to the type of reinforcement used.

No analyses of the samples were made.

**Composition by Volume (%):

Type I	Type II	Type III
100	60	70
	5	
	20	30
	15	

Iso-octane
Benzene
Toluene
Xylene

contract. Two phases, design of the tanks and production of the prototype, should be handled under separate steps of the same contract. Based on laboratory tests and on information supplied by the companies in the list which follows, it is evident that there is no single reinforced resin system which is outstandingly superior to all others. Therefore, the following recommendations are made: The bidder should be given leeway to offer the combinations he has found successful, subject to the recommendations given below and approval by the Chemicals and Plastics Division. The contractor should be required to submit shortly after the award of the contract, one or more sample panels using the same resin or resins and the same reinforcements which he proposes to use in building the prototype tanks. These panels will then be tested and approved. Construction of prototype tanks by the successful contractor should not be permitted until the design phase is completed and approved.

On the basis of laboratory tests carried out to date, sound engineering practices and published data on plastics (see Bibliography), the following are recommendations for design and construction:

1. The principal reinforcement shall be high-strength, essentially bi-directional glass cloth, preferably #181 or #143. Glass mat may not be used except as a central core and then only if necessary to meet the modulus of rigidity requirements without excessive cost or weight.
2. The proportion of styrene or other diluent of the base resin shall be kept as low as possible, consistent with good working properties of the composition.
3. The percentage of inhibitors and of peroxides or other accelerators shall be kept as low as possible, consistent with adequate curing of the composition.
4. Chemical bonding shall be used for assembly of components. If additional strength is required, bolting and/or flanges may be used in conjunction with chemical bonding.

LIST OF POSSIBLE CONTRACTORS

On the basis of published information and information supplied by trade representatives, the following companies are recommended to be considered for design work and for production of prototypes of the 600-gallon tanks. The first 6 companies (a) through (f) report that they have had direct experience in the design and construction of stationary tanks or tank trucks for petroleum products or other liquids. These 6 are considered to be especially qualified, in the order listed. The other companies (g) through (o) are experienced in fiber glass reinforced plastic design and production.

- | | |
|--|--|
| <p>a. Haveg Industries, Inc.
Attn: Mr. Thomas Anderson, Mgr.
New Products Division
West Warren, Mass.</p> | <p>Custom producer of plastic tanks and equipment for use with chemicals and gasoline.</p> |
| <p>b. Carl N. Beetle Plastic Corp.
145 Globe Street
Fall River, Mass.
Attn: Mr. Russell C. Riley, Eng. Dept.
or Mr. Richard Bryan, Gen. Mgr.</p> | <p>Custom producer of plastic tanks and equipment for use with chemicals and gasoline; some have been used in Arabia for petroleum.</p> |
| <p>c. Reinforced Plastics Corp.
Vineyard Haven, Mass.
Attn: Mr. Burnham Litchfield, Pres.</p> | <p>Custom producer of plastic articles including 275-gallon gasoline tanks for Ordnance Corps, US Army.</p> |
| <p>d. The Harford Engineering Co., Inc.
501 N. Union Ave.
Havre de Grace, Md.
Attn: Mr. M. H. Newman
Production Mgr.</p> | <p>Successors to the Luria-Cournand Co. producers of 400-gallon water carriers for the Army Ordnance Corps, and other tank trucks.</p> |
| <p>e. The Heil Co. (Main Office)
Milwaukee 1, Wisconsin
Attn: Mr. R. G. Hampton, Sales Eng.</p> <p>The Heil Co. (Plant)
Hillside, N. J.
Attn: Mr. George Kuhlmen</p> | <p>Custom producers of transportation tanks of from 400 to 4500 gallons capacity. Some of these are insulated and are used for milk. The plastic material used is reported to be suitable for use with petroleum-base fuels.</p> |
| <p>f. Bellingham Shipyards Co.
Squalicum Waterway
Bellingham, Washington
Attn: Mr. R. B. Nolte
Plastics Products Div.</p> | <p>Custom producers of plastic parts for marine use, including tanks for US Navy vessels.</p> |
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- | | |
|---|--|
| <p>g. American Hard Rubber Co.
93 Worth Street
New York 13, N. Y.
Attn: Mr. Vincent B. Stolz
Technical Representative</p> | <p>j. General American Trans. Corp.
Plastics Division
380 Madison Ave.
New York 17, N. Y.
Attn: Mr. Carl E. Holmes</p> |
| <p>h. Beetle Boat Co., Inc.
Foot of Grinnell St.
New Bedford, Mass.
Attn: Mr. R. H. Gee, Sales Mgr.</p> | <p>k. Lunn Laminates, Inc.
Huntington Station
New York
Attn: Mr. Joseph Bova,
Contract Admin.</p> |
| <p>i. The Fibercast Corp.
Box 326
Sand Springs, Oklahoma
Attn: Mr. E. D. Edmisten, Quality Control Mgr.</p> | <p>l. Molded Fiber Glass Co.
4401 Benefit Ave.
Ashtabula, Ohio
Attn: Mr. Robert S. Morrison,
Pres.</p> |

m. Reinforced Laminates Co.
3040 E. Hennepin Ave.
Minneapolis 13, Minn.
Attn: Mr. C. K. Norris, Gen. Mgr.

n. Thompson Trailer Corp.
Pikesville 8, Md.
Attn: Mr. Charles L. Cogswell,
Contract Administration

o. Winner Mfg. Co., Inc.
Box 399
West Trenton, N. J.
Attn: Mr. I. M. Scott,
Pres.

CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations are as follows:

1. It appears feasible to develop a rigid, portable, fiber glass reinforced plastic 600-gallon tank for petroleum fuels.
2. It is recommended that further solvent-resistance tests be run using larger samples of plastics and actual fuels instead of the test solvents used in the tests reported.
3. It is recommended that further engineering work be carried out under a development contract. This should include complete mechanical design of the tank and construction of prototype tanks.

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APPENDIX

SOLVENT RESISTANCE TESTS OF REINFORCED PLASTIC SAMPLES

Tests were run on small samples of reinforced plastics using essentially the same procedures and techniques which have proved successful as screening tests for evaluating the resistance of synthetic rubber compositions to petroleum fuels. Details of the tests are given in Method 6001, "Liquid Treatment Tests, General" and Method 6211, "Change in Volume, Liquid Immersion," both of which are part of Federal Test Method Standard No. 601, "Rubber: Sampling and Testing."

Table I gives the known data on the composition of the 18 samples tested and the results of the tests for the percentage change in volume. Samples were the full thickness of the panel or tube wall, usually were one inch square, and were not buffed. Duplicate tests were run on three plastics; the others were single tests. The liquids used for Types I, II, and III correspond respectively to Mediums No. 4 (low swelling), No. 5 (high swelling), and No. 6 (high swelling) specified in Method 6001. The composition of the liquids is given at the bottom of Table I. The swelling action of these liquids on synthetic rubbers is known to exceed the range of swelling of different commercial gasolines. For this reason, these three liquids were chosen from the ten liquids specified in Method 6001 for the screening tests on plastics.

The change-in-volume test was run as detailed in Method 6211, except that acetone was not used. Each test piece was immersed for 5 days in one of the test liquids in a separate glass weighing bottle with a ground glass cover. Tests were at room temperature, which ranged from about 70° to a maximum of about 85°F. Using a Jolly balance, each piece was weighed in air and then weighed when immersed in water. This was done before and after immersion in the test liquid, and the change was calculated as in Method 6211. Some test pieces were weighed to a tenth of a milligram after removal from the test solution and reweighed daily for the following several days. The loss in weight due to evaporation of absorbed liquid was negligible. Similarly, the change in thickness of some test pieces, as measured with a micrometer before and after immersion, was less than the accuracy of the measurement. Because these weighings and measurements did not give information of value, they were discontinued.

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